MASTER OF SCIENCE
IN
ELECTRICAL ENGINEERING

EXAMINATION OF THE USE OF EXACT VERSUS APPROXIMATE PHASE WEIGHTS ON THE PERFORMANCE OF A SYNTHETIC APERTURE SONAR SYSTEM

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Synthetic aperture sonar beamforming and signal processing relies on properly steering and focusing the aperture beam pattern in order to co-phase all the received signals. Due to the effects of motion in the synthetic aperture sonar problem, the propagation path between the transmitter, discrete point scatterer, and the receiver is time varying. Traditionally, simple approximations are used to determine these propagation ranges and angles of incidence and scatter. Methods to determine these ranges and angles exactly may significantly improve array gain and, therefore, target detection.

This thesis investigates improvements to SAS signal processing algorithms using exact methods for the calculation of the time-varying ranges between transmitter and discrete point scatter, and between discrete point scatter and receiver, and the phase angle of the scattered acoustic signal incident upon the receiver. Using computer simulations, exact range and angle calculations were performed for different scenarios and compared to ranges and angles determined using standard approximations. The exact ranges were then used to determine incident phase, and were again compared to the approximate methods. Comparison of the exact and approximate methods was based on range estimation error and percentage error. Improvements in synthetic aperture array gain using exact phase weights based on exact, time-varying range solutions are proposed.

KEYWORDS: Synthetic Aperture Sonar, SAS, Bistatic Scattering, UUV, Mine Warfare

PROTOTYPE FABRICATION AND MEASUREMENTS OF UPLINK AND DOWNLINK MICROSTRIP PATCH ANTENNAS FOR NPSAT-1

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This thesis addresses the prototyping, measurement and validation of two circularly polarized microstrip patch antennas designed by LTJG Mahmut Erel for the NPSAT-1. The antenna system, consisting of two antennas (receive and transmit) on a ground plane, and their feed systems, was field-tested. The results were compared to the CST® Microwave Studio™ Finite Difference Time Domain (FDTD) software package predictions in order to verify that this design satisfies the NPSAT-1 requirements of bandwidth, free-space radiation pattern and low-profile shape.

KEYWORDS: NPSAT-1, NPSAT-1 Antenna System, Microstrip Patch Antenna, Low Power Satellite Antennas, Low Profile Satellite Antennas, Antenna Prototyping, Antenna Field Tests, Antenna Design

THE UTILITY OF HIGHER-ORDER STATISTICS IN GAUSSIAN NOISE SUPPRESSION

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The properties of higher-order statistics are becoming more and more thoroughly studied in the field of signals processing. One property of great interest is the fact that the cumulants of Gaussian signals disappear entirely at higher orders. Because many noise and interference signals have Gaussian distributions, this property offers the possibility that higher-order statistics may be useful in signal recovery or interference mitigation, which would be of great advantage in military communications, intelligence, or surveillance systems. This thesis examines some of the theory behind higher-order statistics, and discusses the estimation of third-order cumulant values for several random variable distributions. After a minimum sample size has been determined, the study progresses to the frequency domain for an examination of the bispectra of the distributions. The thesis then examines the effects on the bispectrum of combining Gaussian and non-Gaussian signals, and concludes with recommendations for implementing signal processing systems which utilize higher-order statistics.

KEYWORDS: Higher-order Statistics, Statistical Signal Processing

IMPLEMENTATION OF A CONFIGURABLE FAULT TOLERANT PROCESSOR (CFTP)

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The space environment has unique hazards that force electronic systems designers to use different techniques to build their systems. Radiation can cause Single Event Upsets (SEUs) which can cause state changes in satellite systems. Mitigation techniques have been developed to either prevent or recover from these upsets when they occur.

At the same time, modifying on-orbit systems is difficult in a hardwired electronic system. Finding an alternative to either working around a mistake or having to keep the same generation of technology for years is important to the space community. Newer programmable logic devices, such as Field Programmable Gate Arrays (FPGAs), allow for emulation of complex logic circuits, such as microprocessors. FPGAs can be reprogrammed as necessary, to account for errors in design, or upgrades in software logic circuits.

In an effort to provide one solution for both of these issues, this research was undertaken. The Configurable Fault Tolerant Processor (CFTP) emulates three identical processors, using Triple Modular Redundancy (TMR) to mitigate radiation hazards on a radiation tolerant FPGA. With the reconfigurable capabilities of FPGA technology, as newer processors can be emulated, these new configurations can be uploaded to the satellite as software code, thereby actually upgrading the processor in flight. This research used a 16-bit Reduced Instruction Set Computer (RISC) processor as its core. This thesis describes how the Harvard architecture of the processor interfaced with the Von Neumann architecture of the memory. It also explains the process by which errors are detected and corrected, as well as recorded.

KEYWORDS: Fault Tolerant Computing, Triple Modular Redundancy (TMR), Field Programmable Gate Array (FPGA), Single Event Upset (SEU), 16-Bit RISC

PERFORMANCE ANALYSIS OF M-QAM WITH VITERBI SOFT-DECISION DECODING

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This thesis derives design tools for determining and improving performance of communication links that use M-QAM coherent demodulators associated with Viterbi soft-decision decoding (SDD) in Additive White Gaussian Noise (AWGN) and Nakagami-m channels. Performance analyses for 16-QAM, 64-QAM, QPSK, and BPSK associated with up to three convolutional codes, including the one used by the IEEE 802.11a standard and the dual-*k* code, are presented as practical applications. The main tools relate to the analytical derivation of upper bounds of the probability of bit error (P_b) for any M-ary coherent demodulator followed by SDD, a methodology for improving an upper bound of P_b tightening it to realistic data, and the obtaining of the specific $\beta(d)$ spectrum for any convolutional code intended to operate with a certain *M*-symbol modulation. All derivations involve statistical considerations over the AWGN and Nakagami-m channels, as well as in-depth analyses of modulator constellations. The tools and models developed can provide great optimization to bandwidth-limited system designs that require high data rates, especially the wireless ones. Consequently, they have great application to many fields of digital communications, such as cellular telephony, wireless networking, satellite links, ship-to-shore and ship-to-ship communications.

KEYWORDS: M-QAM, Convolutional Code, Viterbi Soft-decision Decoding, Dual-k, IEEE 802.11a, AWGN, Nakagami

SMART ANTENNA IN DS-CDMA MOBILE COMMUNICATION SYSTEM USING CIRCULAR ARRAY TECHNIQUE

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This thesis examines a circular adaptive antenna array used at the mobile station for a typical Direct Sequence Code Division Multiple Access (DS-CDMA) cellular mobile communications system. The primary objective is to reduce co-channel interference of a wideband CDMA cellular network under a multi-path fading environment. The performance of a randomly positioned mobile terminal with a randomly orientated adaptive antenna array in the forward channel (base-station to mobile) of a multi-cell DS-CDMA system was analyzed, and four performance boundaries were established.

A single complex circular adaptive weight in each element channel of a circular adaptive array sufficiently processes narrowband signals. However, in order to process broadband signals, a tapped-delay line (transveral filter) is required. This tapped-delay line is employed because it can adjust the frequency dependent amplitude and phase. The performance of a DS-CDMA cellular system with a mobile terminal equipped with a circular array and a tapped-delay line was analyzed. It has been demonstrated that the optimization process has been extremely computationally expensive and hence minimum taps should be used for practical considerations. The results illustrated that, in general, for a four-element circular array system, a two tapped-delay line would be sufficient to equalize the broadband signal while providing a similar performance level to that of a narrow-band adaptive array system.

KEYWORDS: Smart Antenna, Uniform Circular Array, Hata Model, Rayleigh Fading, DS-CDMA, Tapped-delay Line

UNIFORM CIRCULAR ANTENNA APPLICATIONS IN CODED DS-CDMA MOBILE COMMUNICATION SYSTEMS

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Presently, the uniform linear array (ULA) is the most commonly used antenna system for a sectorized cell system like the commercial cellular systems. However, in many omni-directional cell communication systems, such as ground-based military communications, interest in using the uniform circular array (UCA) has greatly increased. This thesis examines the use of an equally-spaced circular adaptive antenna array at the mobile station for a typical coded direct sequence code division multiple access (DS-CDMA) communication system.

This thesis analyzed the performance of a randomly orientated adaptive UCA in the forward channel (base-station to mobile-station) of a coded multi-cell DS-CDMA system. Using a 3- and 4-element UCA, the capacity and performance of different cellular systems under a range of shadowing conditions, with and without antenna sectoring at the base station, and various user capacities, were simulated using the Monte Carlo simulation. The results for both ULA and UCA were compared and presented in this thesis.

KEYWORDS: Uniform Circular Array, Sectoring, Interference-to-signal Ratio, Hata Model, Rayleigh Fading, Log-normal Shadowing